Air and the School House

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The subject of this study is a single phase of school hygiene.

As a first and indisputable premise on which to base the study, it is proposed to assert the human right to health, and to whatever health is properly contributary; that health is the asset of highest value, either possessable or usable, and that to be robbed of any measure of it is to suffer a predatory loss of a boon inalienable and priceless.

As a second and hardly less debatable premise, it is further proposed to assert that the school is the appropriate place for the wisest, the fullest and the insistent practice of hygiene, and also the most effective field for illustrating and for teaching the principles and practice of that beneficent science.

I.

Considered in its largest sense the inherent, constitutional, and therefore the inalienable, right of the human race is to life, health and happiness. The desperate tenacity with which man holds to life, and to his right to it, is a matter of common knowledge and experience. Life is vital being; health is the fullness, the completeness, of that being; happiness is the joy incident to the experience and reward of that being. Life is that which makes health and happiness possibilities, the sine qua non of those possibilities. It is therefore of all things most prized, and in the first, and to the last, degree contended for as a right,

and held fast to as an experience. It is because of this preeminence of life, solely as a state of being, that its legitimate accompaniments and possessions of health and happiness are too commonly relegated to an undeservedly inferior rank in the order of values of the inalienable rights. Man is so content with the fact and the experience of mere being that he too often fails to aspire to and set a true value upon the largeness and richness and reward of that being which are equally his inalienable right and privilege with being itself. Hence the need of continuous appeal to stimulate him to a knowledge and appreciation of the possibilities and the value of the larger and richer rights of his inheritance as the summit and the highest nobility of a Universe Creation.

The scope of the immediate discussion is confined to the human right to physical health. To prove that, as a whole, human health is miserably in arrears of its attainable possibilities requires no elaborate demonstration. The shortness, the ailments, the suffering, the ineffectiveness of human life are seen upon all sides and are too often read in the faces of the multitude. The unseen and the unread evidence of that lapse are as much greater than the seen and the read as are the hidden tales of the sea vaster than those spread on its surface.

Some students of anatomy and physiology affirm that the normal length of animal life, brute and human, is five times the period required for the full development of the skeleton, or frame work, upon which the body is built. Because of the intelligence with which man is endowed, his superior ability to protect himself by housing and clothing against stress of cold and heat and storm, because of his range and choice of foods adapted to his varied needs, his available aids in medical and surgical science and practice, and skilful nursing and serviceable drugs, man should logically far outstrip the brute in the proportion of his actual to his theoretical length of days.

The reverse is woefully true. The full development of the human frame is reached at the age of twenty-one years,

and theoretical life should therefore run through one hundred and five years. Forty years ago the average life of man was but little more than thirty years. Today, because of enlarged and better diffusion of knowledge relating to the fostering and protection of life, the average age in civilized communities has advanced to and a little passed forty years, and the race has at the present time possessed itself of forty per cent. of its birth right to length of vital being. Brute life,—with an intelligence limited to instinct, with narrowed resources for the sustaining, protecting and advancing of life, beset by the stress of adverse weather, the blight of disease and without man's protection against the menace of destroying foes,—in humiliating fashion far outstrips human life in the stamina, superabundance, superbness and percentage longevity of its life.

The cause of such disparity in favor of brute life is not unavoidably inherent in the constitution and environment of man; but, rather, is made possible in the superior organism and faculties with which he is endowed and which exalt him above the brute, and give to him the powers of intelligence, choice and will. The more complex and refined the organism, and the conditions of its dependence and functions, the more sensitive it is to changes in those dependent conditions. In this respect man pays a high price for his exaltation to the head of the vital terrestrial creation. In his body man is liable to ills from which the brute is either wholly or relatively free. There are infectious diseases which decimate the human race that do not invade brute life. The glory of man,—his faculties and powers which most differentiate him from the brute, of reason, of imagination, of refined and exquisite sensation, of invention,—in these are his dangers as well as his exaltation. Man suffers in himself, and inflicts suffering on others, through diseases, abnormalities and degradations in the uses of his powers and faculties which are unknown to and impossible in the brute. He is the victim of his own evil choices and vices from which the brute is exempt. In his creative power, and in his hold upon, and large industrial

use of Nature's vast store of energy, he is maimed and crushed by the very forces he harnesses.

A study of this matter discloses a situation not creditable to man's present standing in the vital scale. He is yet far from entering into a full possession of his right to life. He is prone to find his satisfaction in the fact, rather than in the fullness, of existence; in days, rather than in length and fulness of days; in conscious being, rather than in the richness and completion of being. In this is the "total depravity" of man, and the rationale of all human and divine altruistic effort to bring man to his better self through a knowledge and due appreciation of the greatness of his right to life in its abundance, to the largest health and the richest happiness.

The theme of this study involves, and is limited to the dependence of life's physical well being on air. For protection against adverse weather conditions, of wind, storm and cold, man devises and builds for himself houses. In doing so he considers chiefly the things which most immediately and forcibly impress themselves on his delicate sensorium. The vital relation to his well being of the purity of the invisible air, which he shuts out by his building, is a matter of relative indifference to him because of his ignorance, indifference, or incredulity. The unseen and not immediately sense-impressing things of life do not appeal to or concern him as do the seen and more forcibly impressing things. He lives in the immediates and the evidents of his day. What he devises and puts up for his protection is likely to become the harbor of atmospheric impurities which ultimately become the causers of depleted vitality and fatal disease. By the act of temporary protection against a tangible and seen danger he invites and hastens premature destruction through occult sources. It is in the region of the occult where the deep sources of life lie, and yet it is there where man's knowledge is most defective and his need of education is the largest.

It is the house which man builds for his protection which must be saved from becoming his destruction,

which the regenerating work must first reach, and in which it must be ultimately done. What the house and home are, the town, the state, and the nation are.

II

Mankind is in sore need of enlightenment touching his inalienable rights, even the primal rights to life. The race must be educated as it is not today before it can know the high value and far reaching meaning of that right. All facts relating to that right are of basic importance, and must be given a large place in all development of human conception, knowledge and rational activity and effort before man attains to his true place in the universal order of creation and vital being.

In this is the highest function of the school, in that education which most closely and fundamentally relates to life itself, to qualify for individual, domestic and community life. Woe must be the ultimate lot of any land where the aim and end of the school is material, industrial, mercenary. These are in the territory of the R's, a letter of subordinate place in all the alphabets of the human race. The Hs have a relatively superior place, and should be given that place practically and permanently. Reading, 'Riting and 'Rithmetic are the distorted trinity of rudimentary action. Hygiene, Health and Happiness are the beauteous trinity of exalted being. In the common schools, as also in the higher, the themes of being should outrank those of incidental and even of fundamental relationship thereto.

Of primary importance is the user, of secondary importance is the tool. The combination of a tool and a fool results in waste,—of material, time, energy, purpose, patience, and generally of the tool itself. Drugs on the shelf of the apothecary cure no disease. In the hands of the novice, or quack, they are quite likely to tempt disease or deal death. In the hands of the trained physician, fitted to use them, they may ease pain, remove obstacles to the restorative work of vital processes, stimulate vital ener-

gies. "The man behind the gun" determines the effectiveness of the weapon. The Hs behind the Rs determine the effectiveness of all the work of our elaborate and costly enginery of education. The Rs are worth all they cost; the worth of the Hs cannot be measured by their cost. The first right of the race is to be, and health is the measure of being. The second right is to the elementary tools through which being may assert itself. The primal rights of life are two: first of being, second of action; the one, of the Hs, the other of the Rs. The school that does not duly guard and foster both, is itself in sore need of primary education.

The public school stands for public good. In everything in which that good may be fostered through the school, should the school be made to serve its largest and broadest purpose. The strength of a nation is not measured by its masses, but by energies multiplied into masses. The health of a nation is the chief factor in its energy. Therefore, as a matter of appropriate service, the public has the right to demand that the school shall serve the interests of the state by continuously teaching and practicing the principles of hygiene.

To adopt the principle, as many ignorant, and therefore reluctant taxpayers do, that it is enough that school houses and school house practices should be as hygienic as the homes and the household habits from which scholars come, is to reason loosely, superficially and unprofitably. Scholars come from hygienically good, and hygienically bad, homes. Shall those who come from the best sanitary conditions be subjected in the school house to the worst home conditions reproduced in the school? Or, shall those who come from the poorest home environment be given in the school the benefit of that wholesomeness found in the homes of the best cared for children? Or, shall the school house be the compromise composite of the home hygiene of all the houses which the school represents? Shall the school be content to simply avoid the most menacing of hygienic dangers? Shall it not rather insist upon, illustrate, and inculcate hygienic excellencies?

The assertion of this paper is that from the school house, as a fountain head, should run out to every home and community of homes it serves, or can serve, streams of largest benefit; not merely knowledge of spelling, penning and figuring; but, more than all, that of life and of living.

The school house is a place, and generally the only place, to which, under a more or less rigid compulsion of law, the public sends its children. Compulsion does not end with that sending. The school house door is not a dividing gate between responsibility on the outside, and irresponsibility on the inside. The responsibility which compels the child to enter the school house door, equally compels the public to exercise a proper care for the child after he has entered. The public is without right to send, if having sent it fails to protect. Its right in sending is limited by its efforts and its success in protecting. It sends to acquire the Rs. It protects to promote the Hs. The ratios of the respective values of the Hs and the Rs fix also the relative weights of obligation with respect to them.

The school, therefore, is the appropriate place for the hygiene, not of the unhealthy homes, nor of the average healthy home, but of the healthiest,—actual and practical. In matters of hygiene the school house should be the teacher of, and object lesson to, the home. In the school house, vital energy should be emphasized above any instrument of its use, health above books, pens or blackboards. And, finally, the building into which the public compels its children to go, and to live and work, that public must maintain in wholesomeness, and the more so as dangers to health increase with the herding of all sorts and conditions of individuals together within confined spaces.

III

The hygiene of the school house includes everything which effects the health of the school house occupants. It begins with the hygiene of location and environment; of soil, of dwellings and of dwellers in the neighborhood; of

occupations and industries which do or do not taint the earth, the sky, the air, the water, or offend the sight or pure sense of the school community. It concerns itself with recreation grounds and facilities, with exercise, with bathing and clothing, with floors and walls, with desks and chairs, with light and color, with school lunches and the home diet, with water supply and drinking cups, with books and pencils, and with such an ethereal thing as air.

Any one of these subjects, fully treated, is quite enough, and some of them are more than enough, for a single hour theme. The limits of the present study are narrowed down to one, and that one, air and the school house.

There is one fundamental fact of our being and activity which at the outset must be clearly understood if the relation of air to life is to be intelligently grasped, and made the basis of correct theory and successful practice in the field of school house hygiene.

All are so familiar in a crude way, with energy and action, with force and motion, with life and industry, that to devote even passing thought to a study of such matters in such a brief discussion as that now undertaken may seem quite uncalled for. Yet, if all that is involved in so simple a procedure as the speaking of one and the hearing of another could be set forth in its deepest and its truest aspect, the disclosure would come to many as a revelation startling in its wonderfulness, if not inspiring in its awfulness.

A speaker speaks, primarily, because there is within his reach an energy ready and waiting his command for action; and, secondly, an intelligence and will which lay hold upon and direct that energy to chosen ends. That energy, put into voice, is lost to the speaker; is given to the air which brings it to the listener's ears; what was part of the speaker's being becomes the air's action, and is no longer his, but is gone, perhaps forever, beyond his command or control, and is now beating with wave and ripple against the tympana of the listener's ears, setting them in vibratory motion, and that motion is transmitted through ex-

quisite mechanism and sensor nerve to the perceiving brain. All is done, the speaking, the air pulsating, the hearing, the perceiving, by one and the self same energy, now the speaker's by possession and control; now gone from him and speeding through the air; now lost to the air and resident in the vibratory motion of the ear drum; now lost to drum and caught by the nerves and carried to the brain;—that is the one-tenth of a second partial history of a bit, an infinitesimal bit, of Universal energy in action; a one-tenth of a second story in a history eternal of that small fragment of energy.

Human agency did not create that energy; human knowledge and will and skill never did, do not now, and never will create so much as that infinitesimal fragment of energy. Men can apprehend and appropriate and direct energy already existing; that is all. It is that faculty which in part differentiates him from the brute. The brute's range of energy resource is limited to processes within his own body. Man discovers, appropriates and uses energy resident in matter outside his body, and which is not and cannot be made a part of his body. Ages ago he spread his sails and built his wind mills to catch the dynamic energy of the winds for driving his ships and grinding his corn, and put the buckets of his wheels into the streams to dip out and to utilize the gravitation energy of the waterfalls to do the work of his factory and mill. And now, in this day of his intensest activity, he is appropriating and using the vast stores of but recently discovered energy resident in the chemical relations in which carbon stands to oxygen. He changes the chemical energy resident in coal and in air into the thermal energy of fire, and changes that into the kinetic energy of steam, and that again into the dynamic energy of enginery and machinery, and so does his prodigious work. By thus laying hold of the eternal energies stored within his reach and for his use in fuel and in air, and in chemical energies elsewhere found, he today propels his steamships, speeds his railway train, operates his mills, carries on his industries, cuts his way through rocks,

tunnels mountains, digs canals and hurls huge projectiles of destruction at his foes. For the doing of all that he does man creates, and can create, no energy. Apart from the eternal energy he is as helpless, as lifeless, as energy-less as a branch cut from its vine. He is more than that severed branch only as he possesses himself of and directs to his purposes the energy of his environment, energy which has been, is now and will continue to be. Now it is within his reach; today he uses it; tomorrow it will not cease to be, but will be for the most part beyond his appropriation or use.

Man, then, is a creature endowed with a beginning of intelligence and of directive will, placed in the midst of an inconceivably vast and eternal flood of energy, a rill of which is now within his reach. He lives and moves and has his being in and because of that energy. He is lifeless, powerless, nothing apart from that. He is industriously great and mighty in proportion as he discovers, appropriates and wisely directs that energy. He is small, a weakling, a degenerate, as he fails to make his own, and to direct to his own uses, that energy, or, having it, dissipates it.

In this simple, all inclusive and to every thoughtful mind awe inspiring truth is hidden the profound secret of human life, human possibility, human destiny. Humanity's life and glory as the offspring of the Eternal, as also humanity's death and ignomy,—as that of the foolish son who sells his birthright for a mess of pottage, or that of the prodigal son who wastes his substance in riotous living,—are all locked in this great truth hidden in man's being.

IV

What has such truth to do with air and the school house? Fundamentally everything. Air in its relation to life cannot be apprehended in its full significance, in its rationale, if the sources of vital energy are obscured from

view. Reason concerns itself with "why?", commercialism with "what?", engineering with "how?". It is the rationale of the subject with which the present study chiefly deals. Why is air a requisite to health and vigor? And why is purity of air essential to physical vitality at its best? These basal questions first considered, attention will then be given to some commercial aspects of the problem which more especially interest the economist, the materialist and the pockets of taxpayers. The engineering phases of the subject cannot be treated in the space at command, and are discussed in another paper.

In the first place, then, what has air to do with life? In its essence the question has already been answered. In its application more remains to be said. The human body is essentially an energy transformer and user. Placed within its reach is food out of the earth on one side, and the oxygen out of the air on the other. Either food or air, without the other, is powerless to develop vital energy, just as much as water or earth would be powerless without the mutual attraction which is technically called "energy of gravitation" to develop dynamic energy. Water alone, or the earth alone, cannot turn the miller's wheel. Water and earth, each possessing energy because of the mutual gravitational relation existing between them, are set in motion by those energies which change into a usable form when that resident gravitation energy is transphased into the active and kinetic form of the waterfall. The energy called gravitation is thus changed to energy of motion in the fall, and the motion of the water, yielded in part to man's paddle which he dips into the stream, is transmitted to the saw and other utilizing machinery.

So also with coal and air; coal alone is inert; the oxygen of the air alone is equally so; yet, by virtue of the relation they sustain to each other in the realm of chemical affinity, they are mutually possessed of energy in the form, or phase, known as chemical energy, which man may change to thermal energy through fire, and draw upon through boilers as he draws the energy out of the stream with the

scooping paddles of his wheel. Thus the gravitation energy resident in the above water and the below earth, and the chemical energy resident in the unoxidized carbon in coal and the uncarbonated oxygen in air are among the principal sources upon which man today depends for his industrial enterprises. The gravitation energy of the earth and the water in the stream is changed by man's apprehension, appropriation and direction into the dynamic energy of the water wheel; and the chemical energy of the coal and the air is changed in the same manner into thermal energy, or heat, and in that phase is harnessed to man's industrial work.

The greater part of the stores of energy in the midst of which man has his transient being are about him in a stable form of potential utility, such as gravitation energy and chemical energy, and that active form which these same energies take when changed, chiefly through man's volition and agency, into phases of actual utility are brief and passing. One energy is in reposeful, the other in active phase. One the mutual pull, or force, of masses under the action of gravitation, or the mutual pull of atoms under the action of chemical affinity. The other, the flow of water, or the motion of the molecules which is known as heat, and which physicists know as thermal energy. Both of these motions,—water in the falls and molecules in vibratory action—are active and transient; they are simply phases of transformation of energy from one type into another. Man is gifted with the power of changing energy forms from those of repose to those of action, and of then using for his purpose those of action.

In the chemical relations existing between one pound of carbon and two and two-thirds pounds of oxygen, there is energy in repose, which, changed into energy of action in the thermal state, is sufficient to do the work of raising a ton weight from the sea level to the summit of Mount Washington. The prodigiousness of man's work today may be roughly gauged by the rate of his appropriation and using of this single stored energy of repose. Out of the "strength of the hills" he is digging the fuel factor in

that energy at a rate represented in three millions of tons of coal a day. In the air about him is a vast store of oxygen estimated at eleven hundred million millions of tons; a supply which by a marvelous, stupendous and ceaseless process of sustained replenishment is renewed as rapidly as it is exhausted.

Until within a few years man has been in ignorance of the immense reservoirs of energy-in-repose at his hand. The sources of the immense industrial strides which have marked the development of manufacturing and commercial growth within the last century are found in the coal of the hills and the oxygen of the air.

That strength of the hills and that quickening spirit of the air, are only man's findings, and are none of his creatings. The power that vitalizes the body, that speeds the train, that propels the ship, is man's only because he can lay hold, and in some measure has laid hold, of the flowing trails of infinite energy, as with awing majesty it moves through the stupendous sweep of a boundless universe,—the infinite "I am that I Am."

What man purposely does with and through fuel and air, he does less consciously with and through food and air. The boiler furnace is fed fuel and is given draught. Man eats food and breathes air. In both the process is one of conversion of chemical energy into thermal energy, of energy of repose into energy of action. The furnace, boiler and engine are, in combination, an energy transformer. The human and the brute body is equally a transformer,—a marvellous furnace, an exquisitely perfect mechanism, in a combination which for dynamic economy the ingenuity of man cannot match in any mechanical creation. The body, supremely fitted to its function, is purposed and fashioned to receive energy stored in food and air, to transform that energy into vital energy, the dynamic energy of muscle, the finer motor energy of nerve, the mysterious and directive energy of brain.

Herein is the basal truth upon which the present study rests. The life of the human body, all its voluntary and

involuntary activities, is energy in action, energy not created of the body, not continuing within the body, not to perish with the body; but energy which was in other forms and in other matter yesterday, is in vital form in the body today, and will be in other form and matter tomorrow. The body is the receiver, the director, the user of such transition energy as it can appropriate out of the infinite store about it. It receives the energy in its chemical form, and transforms it into its vital form. Therein is the rationale of eating and of breathing, the necessity of aerating our bodies, and of ventilating our dwellings and other habitations.

Without air, fuel and food remain useless carbon; without the carbon of fuel and food, air contains useless oxygen. Both are alike inactive in repose without the combination which transforms energy of repose into energy of action.

V.

The process of vital energy production involves change in both food and the air used in the process.The food once so used is not usable again. The air once so used is no further usable in like manner. The principal changes in air resulting from its contribution to vital energy are five: oxygen is withdrawn from the air, an equal volume of carbon dioxide is added to the air, water vapor is yielded and taken up by the air, the temperature of the air is raised by the heat evolved in the process and imparted to it, and organic matter, oozing out through the pores of the skin, and eliminated from the body through the mucous membranes, is floated on the air. The changes correspond to those produced in air by a boiler furnace fire,—oxygen reduction, production of gases, vapor, heat and smoke. To repass the undiluted contents of the chimney through the boiler fire would extinguish it as surely as water would quench it. The rebreathing of undiluted expired air would as quickly put out the vital flame.

The question then presents itself, what dilution of the cast off products and residuals attending the energy transformation processes which issue in vital energy is necessary for the production of vitality at its best? If the question be asked in reference to the food and drink factors in that transformation process, the universal answer would be strenuously emphatic in its demands for a purity of supply which should completely eliminate the body wastes from food and drinks. The very suggestion of contamination of such sort is repulsive in the extreme. No one valuing rightly his own health could knowingly be persuaded to select for even temporary residence a house or a city which discharges its excremental and other sewage up stream and takes its water supply from the down stream of any brook or river, unless it were of torrential proportions.

When, however, that same question relates to the atmospheric factor in the vital energy production process, it is commonly treated either trivially or incredulously. Yet not so if the fire is that of the boiler furnace rather than that of the body. To feed undiluted waste chimney gases to a fire would, by common intelligence, be ranked in the same folly with feeding such fire with ashes, and to mix chimney gases with the air-indraught to fire would be judged as harmful to boiler efficiency as to mix ashes with the coal fed to the fire.

As a matter of practical experience, the quality of air fed to a fire is of larger importance than is the quality of coal fed to it. Ask any experienced fireman as to the first essential for maintaining a good fire and he will reply "a good draught." Without that he can neither build nor keep his fire, however good the coal may be, or however skilful his stoking. Let the draught be good and the coal poor, he can then make and keep a hot fire by dint of hard and skilful stoking.

So also in the matter of stoking, or fire tending; the quality of even that is of larger importance in the matter of fire maintenance than is the quality of coal used in the process. Poor stoking makes wasteful work of the burn-

ing of the best coal, and of the using of the best of draught. Good stoking, on the other hand, may make a fine fire of poor fuel with a good draught. The sequence of importance is, then, first, excellence of air; second, skilfulness in stoking; third, excellence of fuel.

Turning now to the body, the physical energy transformer, the relative values of pure air, stimulating exercise and pure food will be found to be the same as those of draught, stoking and fuel for the boiler system. The exact proportion of oxygen in the air is of vastly greater importance than is the precise proportion of carbon in the food. Even the quantity and quality of the stoking exercise, which stirs up and cleans out the animal fires, is of a larger vital importance than is the proportion of carbon in the food fuel. The average maximum of physical strength and endurance for doing the world's hard work is found in men of the dinner pail brigade, whose food is for the most part coarse and too often ill prepared, and with small reference to exact proportions of sugar, starch and fats, of carbon and nitrogen; but whose abundant exercise in open air does for his vital fires what good stoking does for the boiler fires, which would otherwise become clogged with ash and clinker.

VI.

Because that common, costless, abundant thing, air, envelops man as the great ocean does the fish that is almost lost in its waste of waters, he is prone to think it of commonplace and minor value, and its exact purity as of small account. Yet with marvelous exactness the purity of that waste of air is continuously maintained. Carbon and oxygen in immense proportions are continuously combining the world over in energy transforming processes, the daily combination product of carbon dioxide reaching twenty-two million tons, six million tons of carbon oxidized, and sixteen million tons of oxygen carbonized. And while this stupendous process is proceeding, vegetation is daily ab-

sorbing these twenty-two million tons of carbon dioxide, keeping the six million tons of carbon for leaf and blade of forest and field, and giving back to the air the sixteen million tons of oxygen, so maintaining the richness of the air on one side, and the world's supply of carbon in vegetation on the other.

One, if not the principal, reason for the indifference of the thoughtless with reference to atmospheric impurity is in the general invisibleness of that menace, and its failure to instantly impress itself upon the physical sensorium. The air and, for the most part, its contents, are invisible either because of perfect transparency or the minuteness of that in it which is not transparent. In this case that which is transparent ceases to be apparent, and that which is minute is not impressive. The fallacy of basing reasoning solely on the impressions of sensation characterizes primitive and un-schooled mentality. Yet the energies and causes which lie back of, and are operative in, most visible phenomena are invisible. The swift movement of the great steamer through the sea, and of the flying express over its track, are the motions of aqueous molecules transferred to, and becoming the motion of, the ship and train.

The invisibly minute and imperceptible is there, as elsewhere, in primal relation to the visible and the impressive. Back of, and in causal relation to, the great plagues which have decimated the peoples of cities and nations has always been a mal-aria—a badness of air—which because of complete invisibility has been thought to have been of the genus of an evil spirit. The unseen dust particles in the air of dwellings and the street number from thousands to millions in each cubic inch of air, and among them are often found the microbes of deadly diseases. Into one thousandth of a cubic inch could be crowded the bacilli of tuberculosis in such multitudes that if the individual bacilli making up that crowded colony were evenly distributed through the air of a building of one million cubic feet contents, the number in each cubic foot of that air would be one thousand, and the number

inhaled with the breath fifteen thousand an hour by a single breather. The microbic agencies productive of our infectious and most dreaded contagious and malignant diseases belong in a realm of minuteness too great for detection by the natural sight.

An alteration by so much as an atom in the chemical composition of substances may, and often does, so change the character of a product as to make it hardly recognizable as a relative of combinations to which it is constructively closely akin. Two atoms of oxygen in combination with one of carbon make a gas so harmless that when diluted with air in proportion of one to twenty-five, the mixture may be temporarily breathed with impunity; whereas one atom of oxygen in combination with one of carbon produces a gas so deadly that one part diluted in one thousand of air is quickly fatal. Metallurgists have found that a change in carbon equal to one-thousandth part of the total weight of steel so alters its hardness and ability to resist wear that the degree of hardness attending the presence or absence of that thousandth part of carbon is quickly evident in the life of railroad rails under the stress of use. The variation of a thousandth part of carbon in the composition of the dies which put the nation's impress on its coins changes the steel from that which can sharply stamp forty-five thousand pieces, into that which fails before the forty-fifth impress is made.

So also the variations in the methods of aggregation of the selfsame molecules almost incredibly changes the physical characteristics of the resulting substances. Charcoal, graphite, camphor and the diamond are the same in elementary substance. Ozone is intense, and oxygen mild in oxidizing activity, though the only difference between them is that one is made up of three, and the other of two atoms of oxygen.

What is true of atoms and of molecules in chemical and adhesive combination is equally so of worlds and systems in gravitation combination and celestial balance. Neither immensity nor minuteness is, or can be, free from

the universal law of exactitude in the order, economy or processes of Nature. All solar and stellar combinations are as exactly poised in mechanical balance as are the atoms of the laboratory compound in chemical balance. Let but one of the multitude of bodies in any celestial system forsake its orbit, and the perfect harmony of "the music of the spheres" is broken, until finally chaos may take the place of order, the balance be broken, and "the heavens roll together as a scroll" and "melt with fervent heat." What a stupendous final destruction consequent upon so small an initial departure! In nothing is Nature haphazard or approximate, but in everything, whether minute or immense, inexorably exact. Nowhere and in nothing is it safe to measure the proportions of final issues by the seeming insignificance of initial causes. Everywhere and in everything causes which seem insignificant, issue in results which appear out of all proportion to the initiative. It is the old and familiar story of the rudder and the ship, the tongue and its issues, the little fire and the great matter it kindleth, the wind and the whirlwind, the atom and its transformation of the physical properties of compounds, the diminutive microbe and the devastating plague.

Where conditions are most sensitive and processes most delicate, the results consequent upon causes may be expected to be more marked and decisive than when conditions and processes are neither sensitive nor delicate. The human energy-transforming system is one of exquisite sensitiveness, and of supreme delicacy of adjustment and performance as compared with the boiler system of energy transformation and operation. If, then, it can be clearly shown that the relation of air quantity and quality to the complete performance of a boiler plant is one which seriously affects the economic operation of that plant, it not only may hypothetically, but it may reasonably, be inferred that the vital energy output of the far more sensitive and intricate human system must be at least equally effected by change in atmospheric quantity and quality. The draught through a boiler fire may be so excessive as to put

out the fire. A lesser, though too strong draught, lowers the temperature of combustible gases and carries to chimney as waste an excessive amount of heat produced. On the other hand too little draught fed to the fire results in incomplete combustion of fuel and the heavy waste attending but partially oxidated fuel. For results of highest effect, the draught must be adjusted with precision to the combustion rate to be accomplished.

Waste attends any variation from the exactness of the conditions upon which the completeness of desired results depends. The effect on illuminating flames of minute changes in air from its normal constituent proportions has been already referred to, and further shown by recent experimentation. Remove from the air oxygen equal to one five-hundredth of the air volume, and replace that oxygen by the gaseous product of carbon oxidation, carbon acid gas, and the luminosity of the candle flame drops one-twentieth. That is, a change in air of one produces a change in luminosity of twenty-five. It is highly significant that such results should attend changes so slight in conditions affecting the lifeless, senseless, unimaginative flame of a candle, a lamp, a gas jet, and that there should be such manifest responsive sensitiveness to slight changes in the atmospheric conditions upon which ordinary combustion and illuminating processes depend. The greater the delicacy which attends and affects the combustion process and the luminosity of the flame, the greater the ratio becomes between the producing cause and the resulting effect in the illuminating product. In the concentrated flame of the German student lamp is an illuminating flame of the highest development, intensity and illumination combined with sensitiveness of conditions affecting luminosity. Breathe into the inner tube supplying that flame with air a quantity of expired breath which changes the composition of the total air fed to that flame but one in two hundred, and the brilliant flame assumes a sickly paleness, and dwarfs into flickering smallness useless for illuminating effects.

The higher and more intricate an organism, the larger

and more involved and involving are the effects upon it of any change in the conditions upon which its processes and functions are dependent. A plant has a form of life; in its organization and vital functions it is higher and more intricate than the flame, and is therefore more susceptible than is the flame, to variations from the normal in the conditions upon which its vitality depends. At the Mt. Vernon home of Washington are large conservatories filled now, as in his day, with luxuriant growths of plant and flower. Those conservatories are now heated with hot water circulated in pipe coils within the enclosures. If unprotected, the pipes grow rusty and shabby in appearance. The place is a Mecca of national resort. The conservatories, even their pipes, are on exhibition. An enterprising agent representing a manufacturer of paints interested the inexperienced custodian in protecting and ornamenting those pipes with his paint. It was applied to the pipes when the weather was warm and plants were summering without. All through the hot summer and early fall that paint was given time and air to dry. It dried hard, smooth, glossy, and became all that was prophesied and desired in appearance. It had ceased to emit any odor of paint, or to sensibly affect the air in any way. Moreover, before the plants were rehabilitated for the winter, the pipes were heated for expelling from the paint all possible traces of volatile residuum. The plants were then reinstated, all in a normally healthy condition. It was soon noticed that the foliage began to wilt, and that blossoms faded and drooped, and after a little all the life of the conservatory plants was hopelessly gone. The suspected pipes were then given a prolonged treatment with superheated water. The conservatories were aired day and night, until again not a suggestion of any abnormal quality of air could be detected, nor a trace of anything injurious found in it. A second time the conservatories were stocked with new and healthy plants; and again, the flowers paled, and the leaves, whitening at the edges, withered and died.

Then again those pipes were heated, this time in the hot flame of a plumber's furnace, inch by inch, until brought

to a low glow of heat, and until everything organic and volatile had been expelled and burned from the paint, and from the very iron of the pipes; and then, when again the enclosures had been freely and lengthily aired, the renewed installation of plants lived and grew and blossomed as well provided for plants should live and grow and bloom.

Here, then, is the emphatic evidence of the lifeless flame, and the equally significant testimony of the living plant, to the effects of change in minute degree in the constituent quality of the air. Neither flame nor plant represents the highest and most complex system of organism. For that we look to man, endowed with sensation, with the power and play of thought and imagination, with all their introactive and reflex effects upon the vital flame. What effect has change of air upon the intensity, the brilliancy and the vigor of that flame? What physician does not know it? What to thousands hovering between life and death has change of air meant, from inland to seashore air, from lowland to mountain air? What the quality difference in those airs? What makes one life taking and the other life giving? By what means can the difference be measured? What chemical test so delicate as to determine it? If variations which are so minute as to be termed "traces" are so potent vitally, what shall be said of changes which are so gross as to be easily measured by methods not refined, and which need no delicate balance to detect their presence, but which through rankness and density are often discerned by the sense of smell, and made immediately and conspicuously evident by the dullness and languor in animal or brute life exposed to them? If a change of one in the air produces a change of twenty-five in the brightness of the candle flame, what will a like air change effect in the vital flame?

The answer is incontrovertible in the volume of its facts and in the value of its unimpeachable logic. Because of the complexity, the delicacy, the sensitiveness, the susceptibility of the vital flame, what should be the expected result? If the candle flame pales, why should not the vital flame droop? If the glow of a candle flame changes to a

duller and a lurid hue, why should not the cheeks of the breathers of the air, in which that candle so burns, redden with feverish flush? If when the carbon dioxide of the air changes from the normal, four parts in ten thousand, to twenty parts, the candle loses one-twentieth of its brilliancy, why should not alertness be changed to listlessness, quick and clear insight to the slow grasping of the lethargic mind? the keen edge of mental acumen be dulled? the finest flower and highest color of vital energy droop? rapidity and accuracy of productive work change to the plodding and blundering effort of depleted energy? the exhilaration of work with energy in surplus change to the burdensomeness of toil when life's edge is dulled, and there must "be put to the more strength" for every result achieved?

The quality of air in a school room may easily be such as to effect a change in the clear brow and fine perception of a scholar as great as that of the keen prow and fine lines of an ocean racer transformed into the blunt prow and flat bottom of a canal boat. In attempted answer to such argument it has been said that men have lived and thrived and have done the past great work of the world without any such attention to air quality as is now advocated, and even required by law. Many may remember the school-house and rooms in which their early school experience was had, those crowded, tight, close, stove-heated rooms, all of which conditions have been survived in safety. Why then should not the children of today equally survive like conditions?

Survive!—the very word answers the question. It means, by implication, a menace. The question for that growing, developing, energy acquiring, that sensitive, tender, susceptible school age should never be one of surviving, but of reviving, and of vivifying.

In the years ago, when those, now the older boys and girls, were pent up in stuffy schoolrooms, and when little heed was given to ventilation, the average longevity among civilized races was, as has already been said, from thirty-three to thirty-four years. Now, when sanitation, and with it ventilation, have come to claim and to hold their place among the

essentials to a vitalizing of life, the average years of civilized races has passed the forty year mark. And what, and how many, magnificent stalwarts are found today in men and women among the generation that is crowding the premature gray heads toward the precipitous edge of life's stage!

To have escaped with one's life the dangers lurking in the old schoolhouse does not prove the menace trivial. Because thousands escape the battlefield unscathed, who will be found to affirm that the battlefield is not a place of supreme danger? To learn the degree of that danger who watches the legions of veterans as in annual encampments they march to martial music in long parades through our city streets, but does not rather go to that place of speechless and pathetic eloquence, the country's Arlington?

VII.

The menace of the minute is not limited to cause alone, but includes also effects. Effects which in the initial and immediate are minute, may, and often do, become great when cumulative. A gun trained one-tenth of a degree off the true line of fire departs so little from that line that only the experienced eye of a gunner may detect the deviation; but the path of the projectile fired at the target four miles distant will go thirty-five feet wild of the bull's eye through the cumulative effect of that minute error at the gun.

Likewise in things vital there is the inappreciable initiative, the unavoidable cumulative, the inevitable finality in result. In those who are robust, excess of vitality may conceal the initiative results of exposure to adverse hygienic conditions, and tendencies may be temporarily obscured. Tendency is the thing of primary importance. If tendency is to be determined, then sensitiveness and delicacy in the subject, and in the conditions which affect it, are essential. The direction of an imperceptible air current is not to be determined by throwing a brick into it, but rather a straw or a fluffy feather. Tendencies are best and properly observed only under conditions of delicacy of ad-

justment, of sensitiveness and susceptibility to the action of causes under inspection. The tendency of effects of impoverished and vitiated air is, therefore, not to be most surely discovered by exposing robust life to it. Tenderness most quickly and surely discloses tendencies. The effect of vitiated air on frail vitality is to be noted if the tendency of such environment is to be truly learned. The feeble and puny beginning of life, the baby age, is well suited to that purpose. And the history of its gasping for better breath, and of its dying for want of it, could even the briefest resumé of that story be given, would furnish a decisive demonstration of the tendency trend. In one maternity hospital the death rate for years when ventilation was insufficient was reduced to one-tenth when ample ventilation contributed to better sanitation.

In the case of adults the tendency trend is less evident, yet significant. In the wards for adults in hospitals where, through shock attending accidents or operations or the weakening effect of disease, vitality is at a low ebb, the marked beneficial effects of good ventilation are also found. In the surgical wards of a well-known hospital the death rate has changed from forty-four per cent. with faulty ventilation to thirteen per cent. with free ventilation; and in the general wards from twenty-three without, to six with good ventilation.

It is by no means necessary to limit the field of inquiry to baby life and hospital invalidism. Adults in average health and active life repeat the evidence with significant emphasis. When the U. S. Pension Bureau was housed in scattered and illy adapted and poorly ventilated buildings about Washington, the average of several years of record showed an aggregate absence on sick leave amounting to between eighteen and nineteen thousand days a year. When, later, a much larger clerical force was housed in a new and well aired building the average of absence for an equal period was but little more than ten thousand days. The records of great prisons, and even of army stables, show that the strongest of men, and of brute life as well, are not immune from the baneful influence of impure air.

Could the daily dead be numbered whose lives have prematurely lapsed through the cumulative effects of a want of that air which in its vast abundance and in its sustained purity is free to all, and an inalienable right of man, the record would be appalling.

VIII.

The dead are beyond human reach and helping. The living are the keepers of their brothers, the living. The present study relates to the obligation of the public to the children in the school-houses in the matter of pure air. How much air should be provided for them? If health and vigor were measureable by the quantity of air supplied, there would then be no restricting limit upon our obligation as to the abundance of that supply. The facts, however, are otherwise. Too much air is even more dangerous than too little. Too little means vitiation and stagnation; too much means draughts. Vitiation dulls, stupefies, enervates, depresses vitality, exposes the body to a multitude of waiting and menacing dangers. It cumulatively weakens and prostrates, and gradually kills as by a slow fever. Draught, on the other hand, pierces to the very bone and marrow, as with a quick sword thrust. Its results are acute, pronounced, startling, often painful, too often deadly. Too strong a draught will put out, rather than intensify, a fire. It will also make the vital flame flicker to its extinction.

Moreover, draught effect aside, the vitalizing effect of air is not proportional to the quantity furnished. With each increment of air, the increment of physical benefit derivable therefrom is reduced, until, at length, the gain obtainable from further increase is not commensurate with the cost of furnishing it. There is a primary limit within which the question is one of life and of death; what quantity of air is absolutely needed to sustain life? There is a secondary limit, between which and the first lies the question of the degree of vitalization to be furnished life. Beyond these two there is yet another, what quantity of air will a

breather bear without danger from draughts, atmospheric or economic? The first is the question of simply maintaining the fires; saving them from extinction. The second is one of obtaining from those fires productive work of the highest and most continuous order. The last is one of maximum limit of draught without extinction of fire, or without overbalancing loss.

The question of present interest is the second. What are the profitable minimum and maximum limits of air supply? This is the commercial phase of the question of air in relation to the school room, the profit and loss aspect of ventilation. The question is practically one that any manufacturer might ask with reference to his boiler fires. Does it pay to give them draught? Is it proposed to maintain fires for the mere purpose of keeping them in an existence, like banked fires? or, rather, for the purpose of making them effective to the highest practicable degree in productive work? So the humanitarian asks with reference to school houses, "Shall we ventilate to merely keep our children from death or sickness? or, rather, to fill them to the full with vital energy?" Surely the question of vital economy is not, what least will keep the vital flame from extinction; but, rather, what best will bring and hold that flame to its fullest glow without flickering, or without exinguishing it in draughts.

This culminating question of the present discussion may be briefly answered by a reference to a concrete case —a High School. Certain students, recognized at home and abroad as authorities in matters of vital economy, have found that the effect of the vitiated air of unventilated school rooms is to reduce the work of teachers and scholars to at least seventy-five per cent. of that easily and regularly done in well ventilated rooms. The truth of that assertion has been demonstrated under the author's observation, and has been testified to by teachers of his acquaintance. That declaration bears out the already observed evidence of the candle flame, which for each four parts in ten thousand increase in atmospheric carbonic acid drops one per cent. in brilliancy.

In the case in hand, let the degree of desired ventilation be represented by a rise of carbonic acid gas within the school room of three parts in ten thousand over that existing in out of door air, and let the worst supposedly tolerable ventilation be represented by a similar rise of twenty-one parts in ten thousand. What would be the real cost of that poor ventilation? What the real gain of that good ventilation?

For the sake of definiteness, let it be assumed that the school building accommodates six hundred scholars, and that the per capita cost for the school is eighty-five dollars per annum, or a total of fifty-one thousand dollars per year. Let it be further assumed that the poorer air reduces the value of the work of the school room no more than fifteen per cent.—instead of the more probable twenty-five per cent.—through the dullness, slowness, and other faultiness of work on the part of the scholars and of teachers. That means an immediate yearly loss of fifteen per cent. on fifty-one thousand dollars, or seven thousand six hundred and fifty dollars.

The cost of warming air to so ventilate all the rooms of the building that the carbonic acid increase should be but three in ten thousand, instead of twenty-one, and to maintain such ventilation for six hours per day, would average, in coal burned, two-thirds of a ton per day, or three and one-third tons per week; a total of some one hundred tons per year, at a cost of perhaps seven hundred and fifty dollars. To the cost of fuel for ventilation must be added that of interest on the cost of the ventilating plant, and the cost of repairs and deterioration of that plant, which should not exceed one thousand dollars per year; and a further cost of service required in connection with the ventilating plant, over that involved in a mere heating plant, of possibly three hundred dollars a year; making a total cost for good ventilation of two thousand and fifty dollars per year, against a loss of seven thousand six hundred and forty due to bad ventilation. That seven thousand six hundred dollars loss to the public purse is equivalent to ninety school years, or seventeen thousand school days, immediately lost to the city's children. These losses are to be found in the dull-

ness, laxness, restlessness, the inattention, the labored and blundering work; the impaired power of imparting on the part of the teacher and of recipiency on the part of the scholar; the complaining and insubordinate spirit; the increased occasion for and necessity of discipline; the illness and absences of both teachers and scholars which are the well recognized school-room consequences of faulty schoolhouse hygiene, of a want of a proper appreciation and appropriation of one of the two energy sources upon which physical vitality depends, pure air.

The losses attributable to the vitiated air of school houses are by no means limited to those of the rooms themselves. Inside the school rooms the penalties are many and severe, outside they are more and heavier; life's vitality in the aggregate impaired; the beginning of profitable life work delayed; the laboriousness of that work increased when begun, and the period of its extent shortened; the liability of contracting disease increased through reduced vitality; the expenses incident to sickness made greater; the liability incurred to the greater severity of sickness when it comes; and the handicap invited which burdens and shortens and lends a minor key to all life's after work.

On one side of this question of economy is energizing air in all its vast plenty and perfect purity, and the cheapness of warming it for winter use, practically one cent for each forty thousand cubic feet; and on the other side is the fullest store of vital energy procurable from nature's sources. In times past, present and to come that question has been, is and will be periodically threshed out under the flail of the humane hygienist because of the numbers of men, blind to benefits sacrificed, who have urged, do now and will continue to urge the "saving" of that one cent.

The supply of air to be furnished to healthy high school breathers in order to ensure a reasonable, though not generous, wholesomeness of atmospheric environment is twenty-four hundred cubic feet an hour per capita; or, for a high school daily session, fourteen thousand four hundred cubic feet per capita. The per capita cost in fuel for warming that quantity of air in average winter weather would be

approximately one-third of a cent a day. The weekly cost in fuel of ventilation may therefore be placed at something less than two cents per capita. A school year of fresh school-air costs no more than three days' meals for the scholar in our average homes. What other so large, so lasting benefit could be purchased at so small a price? What other investment yields so rich returns? What parent with a spark of solicitous care for his offspring can possibly begrudge the cost? What taxpayer, caring and paying in this respect no more for his home and the common weal than for his tobacco pouch, can protest against that money investment in pure air without exhibiting symptoms suggestive of inhumanity, if not of insanity?

What then shall be said of committees, to whom are committed so much of the vital as well as the intellectual interests of our children and their future, when they treat ventilation as a luxury for the few rather than as the right of all who have a right to live? What shall be said of janitors more interested in currying the favor of the committee by their records for reducing coal consumption than in increasing the vital energy, the immediate working capacity, and the future productive working power of the hundreds and the thousands whose well-being is, in so large degree, in their keeping? What shall be said of the policy applied to this typical high school, which would save twenty hundred dollars in running expenses, and thereby lose seventy-six hundred in product?

There is no public knee too large for accommodating such offenders, nor any public arm too strong for administering to them the discipline they merit. If what has been said is true, if the source of energy out of which issues life and which makes possible all vital energy is lodged for human taking and using in the foods supplied out of the earth, and in the free air which comes out of heaven, then for him who ignorantly, carelessly, or wilfully stands between man and his birthright, the doors most fit to open for his entrance, keeping and teaching are those of the reforming penitentiary, behind which he should be held until he shall awaken to the knowledge, the sanity and the works meet for repentance.